SHIELDING DEVICE FOR IMPROVING MEASUREMENT ACCURACY AND SPEED IN SCANNING ELECTRON MICROSCOPY

BACKGROUND

1. Field of Invention

This invention relates to electron microscopes, particularly to the fields of scanning and critical dimension-scanning electron microscopy, auto focus systems, and electromagnetic screening.

2. Prior Art

A scanning electron microscope (SEM) subjects a sample being studied to a very freely focused beam of electrons. The SEM causes the beam to scan back and forth over the sample in a two-dimensional pattern or raster. Some electrons are scattered from the sample as the beam traverses it, a process which is known as back scattering. X-rays are also emitted as the impinging electrons are abruptly stopped by striking the sample. These scattering and emission mechanisms are well understood by those familiar with the interactions between electrons and matter. In a SEM the scattered and emitted electrons and X-rays are collected by suitable detectors. The outputs of these detectors are combined to provide a signal representative of the topography of the sample or its structure. This signal can be displayed, stored, and analyzed.

The operation of the a SEM can be automated. Automated SEMs are used in the unattended inspection of objects, such as semiconductor wafers. These wafers generally contain various fiducial markers for the purpose of locating certain structures, such as elements of electronic circuitry, test objects, and the like which are contained in a wafer. Once located, a given circuit or other feature can be inspected for defects in its structure. The defects are noted for later reference.

One measurement in common use in semiconductor manufacturing is called the "Critical Dimension" (CD) measurement. When this measurement is made using a SEM, it is generally referred to as a SEM-CD measurement. Certain dimensions of semiconductor structures must be correct so that devices made from these structures will function properly. That is why these are called "critical dimensions". SEM-CD measurements are normally done on "test targets". These are specially designed structures included on the wafer for test purposes only. If the test targets are the correct size and shape, it follows that other semiconductor devices in their proximity will also have the correct size and shape and will therefore function properly.

Competitive pressures in the semiconductor industry require manufacturers to achieve maximum throughput rates in their production lines. Thus the SEM-CD measurement must be automated, accurate, and fast. The required resolution of the scanned image is typically ±5 nanometers. Generally between 5 and 10 target locations on each semiconductor wafer are surveyed in this way. Measurements must be performed at a rates in excess of 25 wafers per hour, or between 125 and 250 targets per hour, allowing between 14 and 28 seconds per target.

Automating these measurements requires that the working distance (WD) and focal length (FL) of the SEM be accurately known. The WD is the distance between the end of the SEM nearest the sample and the sample itself. The FL of the SEM is the distance from the plane of the objective lens of the SEM to the plane where the electron beam is focused to its smallest point. The WD is generally adjusted up and down automatically. The FL is electrically adjusted, but over a smaller distance than the WD.

The WD is set as follows:

a) a high-quality image of the sample surface is acquired,

b) the spatial frequency spectrum of this image is automatically analyzed,

c) the WD is repeatedly adjusted up and down to provide the highest spatial frequency values in the image, which represent the best focus, and

d) when the spatial frequency maximum is found, the process stops and the final data are recorded.

These steps are repeated as many as 5 to 6 times, in a total elapsed time of 7 to 10 seconds. The procedure is repeated for each target on the sample wafer.

SEM-CD measurements frequently relate to pattern surfaces with dielectric or insulating material layers. These materials are charged by the electron beam of the SEM. The charge which accumulates on these materials creates a local electric field which perturbs the electron beam, causing an out-of-focus and distorted image. The length of time required to establish the optimal WD is critical. Shortening the time over which this measurement takes place improves throughput and reduces the amount of charge deposited on these insulating materials, thus resulting in improved measurement accuracy. However, speeding up measurements results in poor signal-to-noise ratio (SNR) in the detector's signals, thus degrading the accuracy of the measurement. The higher the SNR, the finer the quality of the image available for analysis, and consequently the better the adjustment of WD. This conflict between the need for a high SNR which requires longer measurement time, and charging of the sample which requires shorter measurement times results in a measurement which compromises both goals.

The above disadvantages lead to the use of alternative techniques to establish the optimal WD. One of the most attractive techniques is the optical auto-focus system. Establishing the optimal WD with the use of optical sensors or devices is known as "optical measurement" to distinguish from the SEM-CD measurement, described supra, which uses an electron beam. The optical measurement is used to establish the WD, and the SEM is used only for the CD measurement. The two measurements are performed on a common region. This results in a faster determination of WD and shorter exposure of the test target to electron beam.

The WD is relatively small compared to the dimensions of the polepiece of the microscope. Therefore it is necessary to use a triangulation technique for the optical auto-focus. The use of optical triangulation on a patterned surface causes non-uniform scattering, non-uniform absorption, non-uniform reflections, interference, and phase shift of the reflected light. These affect the measurement accuracy and introduce a measurement error known as "drawback" error. "Drawback" is an error in the WD measurement resulting from surface irregularities on the sample. For example, a SEM with a depth of focus of 0.5 micrometer can perform a CD measurement with the required 5-nanometer resolution. However this implies that the measurement for determining the optimal WD must be accurate to within less than ±5 micrometer. Because of the drawback error, the use of a simple optical triangulation technique does not result in the required accuracy.

Several techniques have been developed to overcome the "drawback" error. The two most effective techniques are described in U.S. Pat. No. 5,298,976 to A. Shahar et al. (1994) and U.S. Pat. No. 5,311,288 to A. Shahar (1994). The